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ASSURANCE - A benchmark exercise on risk analysis of chemical installations

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Introduction

Risk analysis is a discipline, which has constantly been gaining interest over the last two to three decades among the process industry community. Especially, the major industrial accidents that occurred during the years, as the major accidents in Seveso (1976), Bhopal and Mexico City (1984), and Flixborough (1974), contributed to that interest. Risk analysis is a very complex discipline. During the investigation of a chemical plant, to fulfil the objectives for a specific risk analysis, the analysts have to deal with a wide variety of aspects ranging from organisational to technical items. Nowadays, a risk analysis is often demanded by the national or local authorities to judge the safety level and thus the acceptability to continue operation of a specific plant. It is also in the interest of the managers of a plant to minimise stops in production and of course to avoid incidents, which might harm the staff. The situation in which the risk analysis approach is applied is often in the design phase of the construction of a plant or when certain changes on an existing plant are under consideration. A full-scale risk analysis includes the following topics:

accident identification	*to find the parts of the installation, which are of importance with respect to safety. This includes the quantities and properties of chemicals used.*
analysis of accident scenarios	*to describe the possible modes how an accident is developing e.g.: a malfunction in a valve triggers other failure modes and gives a release of a dangerous compound to the environment threatening humans*
analysis of frequencies and consequences	*the accident scenarios are analysed more thoroughly. The probability of a scenario occurring and consequences of the scenario are calculated. The consequences are often measured as*

	impact on human health or mortality. Also the environmental impacts might be a measure.
evaluation of the total risk	*the final evaluation of the risk includes a ranking of the scenarios found and might be expressed as a sum of the risk of all the scenarios. The probabilistic approach will define the risk as the product of the frequencies and the consequences. The deterministic approach is based on the possible consequences only.*

Different approaches are applied in the European countries. In some countries a probabilistic approach is used describing the risk as a function of the consequences and the frequency of an incident. Usually the function is expressed as the simple product of the consequences i.e. expressed as the societal risk times the frequency of the incident to occur. Sometimes the consequences are weighted more than the frequencies to enhance accidents with catastrophic consequences but low frequencies. In other countries a deterministic approach is used focusing on the consequences of an accident.

All the different topics and philosophies will give rise to some uncertainty, which might influence the final outcome in the ranking of the accidents. Therefore, it has been stated elsewhere that "*Risk analysis of technical systems is more an art than an exact scientific discipline"* This rather provocative statement is characterising another situation one has to deal with during a risk analysis. That is the problem of complexity. Real plants are usually very complex and a risk analysis has to cover not only the technical implementation with all its single components and controlling equipment, but also the system as a whole with the various interactions of components and acting / reacting human beings. Thus skills, organisational culture and (safety) management related topics have also to be considered. Not to speak about the specific meteorological and environmental conditions and interacting /interfering technical systems which are not directly part of the plant in the specific analysis. To be able to deal with this complexity it is important to make simplifications, which should make the risk analysis operational. The art in this sense is to find simplifications e.g. scenarios that are valid for the specific processes and representative for the overall risk at the site.

The project

On that background the EU-benchmarking project ASSessment of Uncertainties in Risk Analysis of Chemical Establishments or its acronym ASSURANCE has been established in 1998 (ENV4-CT97-0627) aiming to improve the understanding of the sources and types of the uncertainties connected with a risk analysis. The project is partially funded by the European Commission, under the Environment and Climate Programme of the Commission's Fourth Framework Programme for Research and Technological Development. A better understanding of the uncertainties in risk analysis is an important and actual subject. According to the EU's Seveso directives, its is obligatory for process plants and /or storing facilities dealing with dangerous substances (defined in the directives) to provide a risk analysis to the competent authorities. Therefore, it is of European interest to secure that these analyses are as uniform as possible in the different EU countries.

The objective of the ASSURANCE project is to address the uncertainties within the different topics or stages of a risk analysis. About 10 years ago a similar project was performed. The Benchmark Exercise on Major Hazards Analysis (BEMHA)[1)] was carried out during the period 1988-1990 under the co-ordination of the Joint Research Centre (JRC), and partial funding of the European Commission, with the participation of 11 teams from several EU countries. At that time very large differences in the final outcome of the risk analyses were observed, but in this former benchmark exercise it was not possible to analyse the sources of uncertainty in sufficient details. This will be pursued within the ASSURANCE project.

The project is subdivided into three phases, a qualitative analysis, a quantitative assessment and the investigation of specific case studies, respectively. Between these phases workshops are organised to discuss the results in great detail and to be able to evaluate the uncertainties for every phase. This also includes that after the end of a specific phase a new common basis for the next one is established to prevent that possible misunderstanding might influence the following phases of the analysis.

The different phases have the following objectives:

a) the qualitative phase is meant to make analysts familiar with the plant and to identify the risk and possible failure types with a method chosen by each of the

[1] Contini, A. Amendola and I. Ziomas: Benchmark exercise on Major Hazard Analysis: Vol1. Description of the project, comparison of the results and conclusions. EUR 13386 EN (1991)
A. Amendola, S. Contini and I. Ziomas: Uncertainties in chemical risk assessment: Results of a European benchmark exercise. The Journal of Hazardous Materials. 29 (1992) 347-363

participants. This outcome will be evaluated and will be further used as a basis to define the input for the next phase.

b) the quantitative phase in which the outcome of the risk calculations are compared with each other. The calculations are based on a number of scenarios agreed on at the workshop for the qualitative analysis. This will result in a comparison of different approaches to assess the risk induced by a specific accident scenario.

c) last, the third phase will be the detailed calculation of some specific cases studies which might be e.g. a release of ammonia through a hole under certain conditions. These case studies will give insight in the uncertainties connected with numerical calculations and models for the description of physical phenomena, e.g. atmospheric dispersion codes.

The partners

The ASSURANCE project is a co-operation of nine institutions from seven European countries. The partners with large experience in risk assessment participate in the project under the joint co-ordination by Risø National Laboratory and the EU's Joint Research Centre, JRC. The participants are:

- Det Norske Veritas , Ltd. , United Kingdom
- Health and Safety Executive, United Kingdom
- INERIS, France
- NCSR Demokritos, Greece
- TNO, The Netherlands
- Universitá di Bologna, Italy
- VTT, Finland
- JRC Ispra, Italy
- Risø National Laboratory, Denmark

The reference plant

As a reference plant an ammonia storage facility has been chosen, including a pressurised and a cryogenic storage. Real installations have been chosen to make the ASSURANCE project as realistic as possible. The participants have visited the plant once for a two days period during the "documentation and plant familiarisation" phase of the project. Prior to that visit all participants had the opportunity to get familiar – at some extent – with the plant reading the provided documentation. The on-site visit was followed by an extensive "questions-and-answers" procedure, while issues not resolved even after this procedure were addressed by adopting *common assumptions*. Nevertheless, as the plant information is confidential, the storage plants have been anonymised by the invention of virtual surroundings and virtual meteorological conditions. The virtual map with the reference location and surroundings of the site is shown in figure 1.

The status of the project

At present, the hazard identification and qualitative analysis phase of the project has been completed and the results are being analysed. The objectives of this phase are to assess the state-of-the-art in hazard identification, to get insights in the various techniques used, to reveal and investigate any discrepancies in the scenarios identified and to assess their impact in the following phases of the project.

The partners used a number of different techniques. These include HAZOP, Master Logic Diagram (MLD), Structured What-IF Technique (SWIFT), Hazard Identification by Area Audit (HIAA), Function analysis and Hazard and Consequences Analysis, HAZard Screening Analysis (HAZSCAN), and the use of (national) standard checklists based on accumulated experience from past accidents and past studies. These methods have significant differences but also similarities. In an attempt to categorise them, three groups may be distinguished:

- Methods based on a top-down analysis, mainly represented by the Master Logic Diagram, which has a form similar to Fault Trees, starting from a top event and going down to combinations of basic events, capable to provoke an accident.
- Methods based on a bottom-up analysis, like HAZOP, SWIFT, HAZSCAN and FMEA, which investigate whether deviations of the process variables and failures of individual devices can provoke a major accident.
- Methods based on the systematic use of standard checklists, after division of the plant in areas. Here, the accumulated experience from past accidents and studies is combined with systematic rules to identify the areas that deserve a more detailed analysis.

At the moment, the results of the quantitative phase are finalised by the partners and will be compared during spring. The case studies, the comparison of all the results and the dissemination of results are expected to be finished up to the end the year.

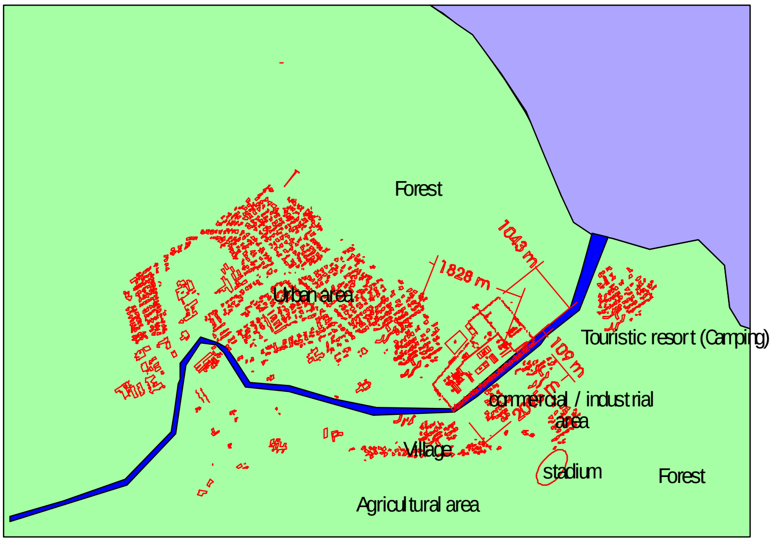

Figure 1 Virtual location and surroundings of ammonia storage plant

Acknowledgements

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